Caribbean Recruitment of Florida's Spiny Lobster Population

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The Florida spiny lobster, *Panulirus argus* (Latreille) is an animal of considerable importance to Florida fisheries. The principal fishery is centered in the Florida Keys and southeastern Florida, but it ranges throughout the Gulf of Mexico and along the east coast of the United States to Beaufort, North Carolina (Moore, 1962).

Previous reports have been published on various phases of the biology of this animal. Crawford (1922) wrote on spawning habits and artificial hatching. Crawford and De Smidt (1922) covered life history, utilization, and the findings of a spiny lobster hatchery formerly operated by the U. S. Fish and Wildlife Service at Key West. Smith (1948a, 1958) dealt with the fisheries generally and made notes on life history, methods of capture, markets, and legal regulations. Dawson and Idyll (1951) reported on conservation methods. Lewis (1951) described the phyllosoma larvae and was first to mention that foreign recruitment may take place. Later Lewis, Moore, and Babis (1952) reported on the post-larval stages. Robinson and Dimitriou (1963) published on the present and past status of the fishery. Ingle et al. (1963) proposed a possible Caribbean origin of Florida's spiny lobster populations and were the first to emphasize the importance of the Yucatan Straits in such recruitment. Several mimeographed reports have been prepared by the University of Miami on the production of marketable lobsters. The present summary provides an extension of the work reported by Ingle and co-workers.

Methods and Materials

Between August 1962 and August 1963 eight trips were made through Florida Straits to the Yucatan Straits for the purpose of collecting plankton. Samples were taken during the day and night when work was underway. Some cruises and sampling were terminated before reaching the Yucatan Straits, as weather and rental boat fees governed the number of days work on each cruise. During the eight trips 413 samples were taken and a total of 6931 phyllosoma larvae belonging to the genus *Panulirus* were collected.

Standard tows were made at random with a conical California-

TABLE 1

Vertical distribution and diurnal migration of phyllosoma
Cruise number 7, June 1963. Number collected by each net by day or night

Station Number	Day		Night	
	*300/s	Surf.	*300/s	Surf.
1	5	0		
2	14	0		
3	11	0		
4			0	25
5	21	1		
6	13	0		
7	5	1		
8	0	0		
9	1	0		
10			1	62
11			5	80
12			24	245
13			4	21
14	Trawl Sample			
15	35	4		
16	14	0		
17	14	0		
18	41	0		
19	36	5		
20			24	153
21			28	162
22			1	4
23	0	0		
24	1	0		
25	0	0		
26			5	31
27			1	272
28	Try Net			
29	Try Net			
30	1	0		

*Oblique tow 300 foot to surface.

TABLE 1 (Continued)

Vertical distribution and diurnal migration of phyllosoma
Cruise number 7, June 1963. Number collected by each net by day or night

Station Number	Day *300/s	Day Surf.	Night *300/s	Night Surf.
31	22	0		
32			22	0
33			51	69
34			12	4
35			0	10
36	66	0		
37	44	0		
38	6	1		
39	32	0		
40			4	14
41	19	0		
42	2	0		
43	48	0		
44	11	0		
45			9	6
46			21	76
47			21	107
48			15	0
49	5	5		
50	2	1		
51	6	0		
52	36	0		
53			17	8
54			3	60
55			4	399
56			8	12
57	9	2		
58	21	0		
59			26	11
60	0	0		

*Oblique tow 300 foot to surface.

type plankton net with a diameter of one meter at the mouth and about 15 meters in length. The main body of the net was constructed or number 30 grit nylon gauze with a finer section of number 56 grit nylon gauze at the cod end. It was lowered into the water to a depth of 150 or 300 feet and was then brought to the surface over an oblique tow which brought it from scheduled depth to surface in 30 minutes. At the same time another net of the same type, or of ½ meter in diameter in some cases, was towed just below the surface. Phyllosoma larvae were collected in both nets. Samples were preserved immediately in 5 per cent formaldehyde. Later they were washed, then stored in 3-5 per cent formaldehyde buffered with borax and marble chips.

In the laboratory all phyllosoma larvae were removed from plankton collected in each sample. Various known and unknown species were separated and the number of larvae for each species recorded. Total length, measured from the apex of the angle formed by the eye stalks to the tip of the telson, and the possible stage of development were recorded. Tables 2-6 deal with the phyllosoma larvae of only *Panulirus*.

The Phyllosoma Larvae

The phyllosoma larvae of the Palinuridae (typical spiny lobsters) and the Scyllarides (sand or shovel-nosed lobsters) are leaf-like and transparent plankton.

The colloquial name stems from Leach (1816), who gave such larvae the generic name *Phyllosoma*. Other workers notably Guerin (1830), Richters (1873), and Ortmann (1893), carried on the name in the belief that these forms were adult. White (1847) gave the adult form of a spiny lobster the generic name *Panulirus*. It was not until the early 1900's that many zoologists simultaneously discovered that the phyllosoma were the larval stages of spiny lobsters. Although *Phyllosoma* has priority, it has been used exclusively for larvae, and the International Commission on Zoological Nomenclature recently suppressed *Phyllosoma* in favor of *Panulirus* (Von Bonde, 1932).

The long larval life of phyllosoma is well documented by Smith (1948b), Sheard (1949), Lewis (1951), Johnson (1960a), and many others. The wide geographic dispersal, via ocean currents, is shown by Gurney (1936), Smith (1948a), and Thorson (1961).

Because *P. argus* is the commonest spiny lobster in the area of this study as well as in the Caribbean, the area of possible recruitment, it is assumed that the majority of phyllosoma reported upon here belong to that species. Probably some are of the species *P. guttatus* (Latreille) and *P. laevicauda* (Latreille), both of which are reported in scattered populations throughout the areas of study by Holthuis and Zaneveld (1958), Holthuis (1946), and Smith (1948b). There is no published literature describing laboratory-reared phyllosoma of *P. argus, P. guttatus,* or *P. laevicauda,* and no one has ventured to describe the larvae of *P. guttatus* or *P. laevicauda* from planktonic collections. Lewis (op. cit.) described from plankton 11 stages in the larval development of *P. argus*. Although our data are not in complete agreement with those of Lewis, we provisionally accept his designations. It appears there could be intermediates between many of the stages Lewis describes, but little more than conjecture could be added without laboratory raised material.

For 300 *Panulirus* phyllosomas selected at random, an attempt was made to separate the three species meristically, by comparing such body parts as fore-body width to total length and fore-body width to hind-body width. These ratios failed to show any specific differences. To further check this method the same *Panulirus* phyllosomas were plotted against an equal number of phyllosomas of *Parribacus,* of the family Scyllaridae. Phyllosoma of these two genera are similar in body shape, but the two are easily separable on morphological characteristics. The graphs failed to show a difference between the two genera until the very late stages, and then only because *Parribacus* grows much larger as a phyllosoma.

From work of Saisho (1964), who compared the first stages of several species of *Panulirus,* and from our own observations on *Parribacus* (Sims, 1965), it does not appear to be possible at present to distinguish between the phyllosomas of closely related species.

SURFACE CURRENTS AND LARVAL MIGRATION

Ocean currents affect the distribution of food for fish, they warm or cool areas of the sea so that certain species of marine life might dwell there, and they aid in the distribution and transmigration of the eggs and larvae of these species. Consequently, a knowledge of currents is essential for the understanding of the variations in abundance of marine animals that depend on them.

TABLE 2

Monthly data for Area I, latitude 20-22° N

Date	Number Collected	Size Range	Mean Stage	Mean Deviation	Modal Stage	Modal Size	Number Samples	Per cent with Larvae	Avg. Temp.	Avg. Sal.	Moon Phase
Aug. 1962	799	1.5-23.0	5	7.7	5	5.0	10	100	29.7	38.2	F.Q.
Sept. 1962	0	—	—	—	—	—	—	—	29.0	37.6	F.Q.
Oct. 1962	9	1.6-11.2	—	—	—	1.8	5	60	28.6	37.9	F.Q.
Dec. 1962	11	2.2-18.2	7	13.6	7	—	4	50	25.6	39.0	F.M.
Jan. 1963	0	—	—	—	—	—	—	—	25.0	38.0	F.M.
Apr. 1963	1001	1.5-8.5	1	0.35	1	1.7	3	100	25.0	37.5	N.M.
June 1963	716	1.5-23.5	6	17.8	6	1.8	43	69	28.3	37.3	L.Q.
Aug. 1963	0	—	—	—	—	—	—	—	29.0	—	F.M.

Published studies on the surface currents of the Caribbean Sea and Gulf of Mexico (Sverdrup et al., 1949; Leipper, 1954; Stommel, 1958; Drummond and Austin, 1958; Stewart, 1962; Ichiye, 1962; Day, 1961; Salsman and Tolbert, 1963; Tapenes, 1963; Wust, 1964) indicate that the currents of the Caribbean, via the Yucatan Straits, may be of importance in seeding Florida and the Gulf of Mexico with tropical marine life. These wind driven currents of the Caribbean, after going through numerous local eddies and gyres along shorelines, flow into the narrow straits between Cuba and Yucatan. After leaving the Yucatan Straits the water fans out into various parts of the Gulf of Mexico. Water on the eastern edge of the straits turns to the right to enter the Florida Straits and Gulf Stream, water mid-way in the straits flows northward into the Gulf of Mexico where it (1) enters the so called "loop current" (Salsman and Tolbert, 1963; Univ. of Miami, 1957), which flows first northward toward the United States coastline, then turns south and enters a clockwise eddy flowing along the continental shelf of Florida's west coast; or (2) after a northward flow turns to the left and enters a counterclockwise eddy that flows along the coasts of Mississippi, Louisiana, and Texas. Water on the western side of the straits flows into the southwestern Gulf and Campeche area. There is an indication that some of this water leaves the Gulf by subsurface and counter currents (Leipper, 1954; Salsman and Tolbert, 1963). Leipper (1954) gives a generalized current pattern of the surface currents of the Gulf of Mexico and Yucatan Straits.

There is biological evidence that tropical Caribbean fish and invertebrates are carried to Florida by these currents (Caldwell and Briggs, 1957; Briggs, 1958; Caldwell, 1959; and Dawson and Idyll, 1951). Cuppy (1917) and Arendt (1963) show that ocean currents transport large numbers of "sea beans" from the Caribbean to the coasts of the Gulf of Mexico and east Florida.

With this oceanographic and biological evidence in mind we initiated a drift-bottle study which would help establish the rate of flow of the surface currents in which the phyllosoma probably travel. The data discussed herein cover work during the spring and summer of 1963, with notes on a small drop made in the fall of 1962.

The release of drift-bottles was made in conjunction with our plankton sampling cruises. Bottles of various types were dropped

TABLE 3

Monthly data for Area II, latitude 22-24° N

Date	Number Collected	Size Range	Mean Stage	Mean Deviation	Modal Stage	Modal Size	Number Samples	Per cent with Larvae	Avg. Temp.	Avg. Sal.	Moon Phase
Aug. 1962	136	1.6-15.0	4	13.1	4	3.5	14	86	30.1	37.6	F.Q.
Sept. 1962	403	1.5-26.0	7	18.1	7	5.2	30	64	29.6	38.3	L.Q.
Oct. 1962	457	1.5-23.2	4	16.7	4	4.0	27	82	29.3	37.5	F.Q.
Dec. 1962	164	1.5-25.1	7	10.6	7	8.2	32	46	25.4	38.7	F.M.
Jan. 1963	191	2.3-25.2	6	12.6	6	7.2	19	61	25.6	38.4	F.M.
Apr. 1963	158	1.4-21.0	1	24.8	1	1.7	56	48	27.0	38.0	N.M.
June 1963	1843	1.5-20.1	6	17.1	6	1.7	51	76	28.1	38.0	L.Q.
Aug. 1963	353	1.5-23.3	7	14.1	7	5.2	14	92	29.0	—	F.M.

during cruises in the months of September and October, 1962, and April, June, and August of 1963. Fig. 1 shows the approximate location of each release. Table 7 gives a complete list of the returns to date.

DRIFT BOTTLE RELEASE AND RETURN DATA

During the fall of 1962, 20 bottles were released in the Yucatan Straits. One was recovered 18 days later at Snake Creek bridge in the Florida Keys, a distance of more than 360 miles, with a minimum rate of 20 miles a day. Another was found at Key Largo 119 days after release; as this bottle was found high on the beach it may have been there for some time. A third bottle released toward the western side of the Yucatan Straits, was recovered after 210 days at Matagorda, Texas.

In April, 1963, 212 drift-bottles were released in groups of 6 along a course from Dry Tortugas to Alacran Reef and then south-

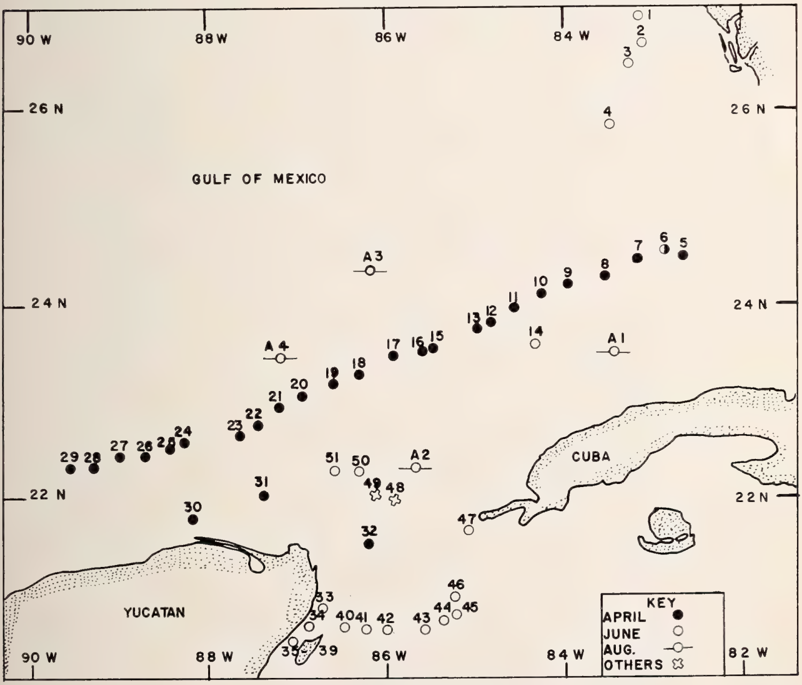

Fig. 1 Drift-bottle release locations (from U. S. Coast and Geodetic Survey Chart No. 1007).

TABLE 4

Monthly data for Area III, 24-26* N

Date	Number Collected	Size Range	Mean Stage	Mean Deviation	Modal Stage	Modal Size	Number Samples	Per cent with Larvae	Avg. Temp.	Avg. Sal.	Moon Phases
Aug. 1962	129	1.5-5.5	1	0.3	1	1.7	4	100	31.2	36.5	F.Q.
Sept. 1962	54	1.5-19.0	1	22.2	1	1.6	12	41	29.7	37.0	L.Q.
Oct. 1962	59	1.5-19.5	4	13.8	4	4.0	7	72	28.7	36.9	F.Q.
Dec. 1962	30	1.8-17.9	6	17.3	6	3.2	20	45	23.7	37.9	F.M.
Jan. 1963	7	3.2-20.2	7	15.7	7	3.2	7	42	24.1	38.6	F.M.
Apr. 1963	85	1.6-20.0	5	12.2	5	5.5	18	50	26.0	37.2	N.M.
June 1963	154	1.5-19.7	1	17.7	1	1.7	21	57	28.2	37.8	L.Q.
Aug. 1963	172	1.7-26.2	2	26.8	2	2.2	15	87	29.0	—	F.M.

west to the Yucatan Straits. At some stations soft drink bottles (161) were released for the U. S. Fish and Wildlife Service Biological Laboratory, Galveston, Texas. It is interesting to note that most of the bottles released between Dry Tortugas and 88°35′ west longitude were recovered in the Florida Keys and on the Florida east coast. Those released near the Tortugas showed more returns in the Florida Keys than did bottles released west of there. The one exception was station 20, whence one recovery was made at Grand Isle, Louisiana, and another at Veracruz, Mexico. All the bottles released west of 88°35′ W, were recovered from the coasts of Texas and Louisiana. Bottles released along the north coast of Yucatan and in the western Yucatan Straits were found in Florida, the Bahama Islands, Texas, and Louisiana. According to current charts all these bottles should have stranded in the northwestern Gulf. Observed returns can only be explained by the existence of uncharted eddies or by the effect of local wind and tidal conditions after the initial dispersal. The effect of wind on drift-bottles is shown by Chew et al. (1962), who reported on the abnormalities in returns of drift-bottles released in the wake of hurricane Carla. The general effect of wind on surface and subsurface currents is discussed by Sverdrup et al. and by Leipper. The fact that no recovery was made from station 32 in less than 92 days suggests that the bottles may have spent some time traveling around before being caught in a current that carried them ashore. To date 24 per cent of the bottles released in April, 1963, have been recovered.

In June 1963, 434 of our own drift-bottles and 135 bottles provided by the Fish and Wildlife Service were released, mostly in or slightly south of the Yucatan Straits. The quickest return from this area was 65 days, and the mean number of days for all recoveries was 120. This would suggest that the bottles may have been retained for it was shown by the fall release that such a trip could be made in as few as 18 days. Again, bottles released on the western side of the Yucatan Straits were recovered from Jacksonville, Florida, to southwestern Texas. To date returns have reached 23 per cent of those released.

Only 192 bottles were dropped in August, 1963. They were released at four sites in and just north of the Yucatan Straits. Only two stations have yielded returns. From Station A2 recoveries were made on the Florida east coast and at Port O'Connor, Texas. From

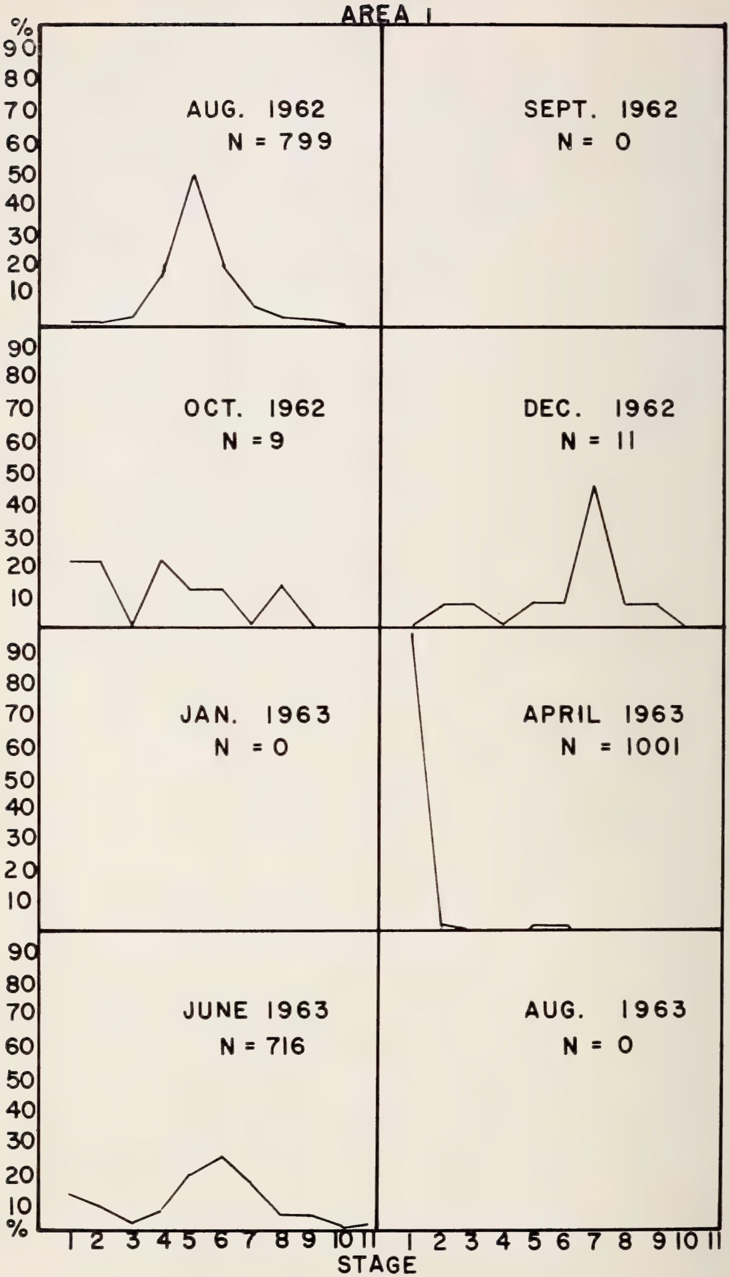

Fig. 2. Monthly occurrence of larval stages in Area I.

Station A4 returns were made from the east coast of Florida only. The transport appeared to be much faster at the time of this release. One bottle reached Delray Beach, Florida, in 20 days, a rate of not less than 30 miles a day. The mean rate for all returns was 50 days or about 12 miles a day. We have recovered only 7 per cent of those released.

POSSIBLE INTERPRETATIONS OF DRIFT-BOTTLE DATA

Data thus far developed from this study indicate that the rate of flow of the surface current from the Yucatan Straits to Florida is sometimes, at least, as fast as 30 miles a day. Such rapid transport could have important bearing on the recruitment of phyllosoma larvae. Lewis (1951) feels that the length of the planktonic life of *P. argus* is more than 6 months. Other workers (Gurney, 1936; Johnson, 1960a; Prasad and Tampi, 1959) predict similar lengths of time for other species. All estimate that 9-13 stages develop during this interval. Saisho (1962) was able to raise the larvae of *P. japonicus* to the eleventh phyllosoma stage in 90 days. However, his stage XI is equal in size and development to stage V as described by Lewis. Saisho interprets this to mean that there must be many more stages in the development of the larvae than past studies have indicated. The opinion shared by Saisho (1962), George and Cawthorn (1963), and Inoue and Nonaka (1963) is that the length of time between ecdyses varies with age and becomes increasingly longer as the phyllosoma mature. Saisho's work on *P. japonicus* showed that the time between stage I and II averaged 7.4 days, while the time between stage X and XI averaged 13 days. From these data we may assume that the length of time from stage I to the last stage in *P. japonicus* must be more than 6 months and that the total number of stages must be more than 11. The same is likely true of *P. argus*.

When applied to our drift-bottle data, these findings have interesting cannotations. For example, the data shown by drift-bottle No. 77A, which traveled from the Yucatan Straits to Snake Creek bridge in the Florida Keys in 18 days, suggest that even at this rate of transmigration any first stage phyllosoma hatched in the Yucatan Straits undergoes two ecdyses before reaching Florida. Therefore, any first stage phyllosoma larvae found in Florida waters must be the spawn of local populations. Deductions of this type

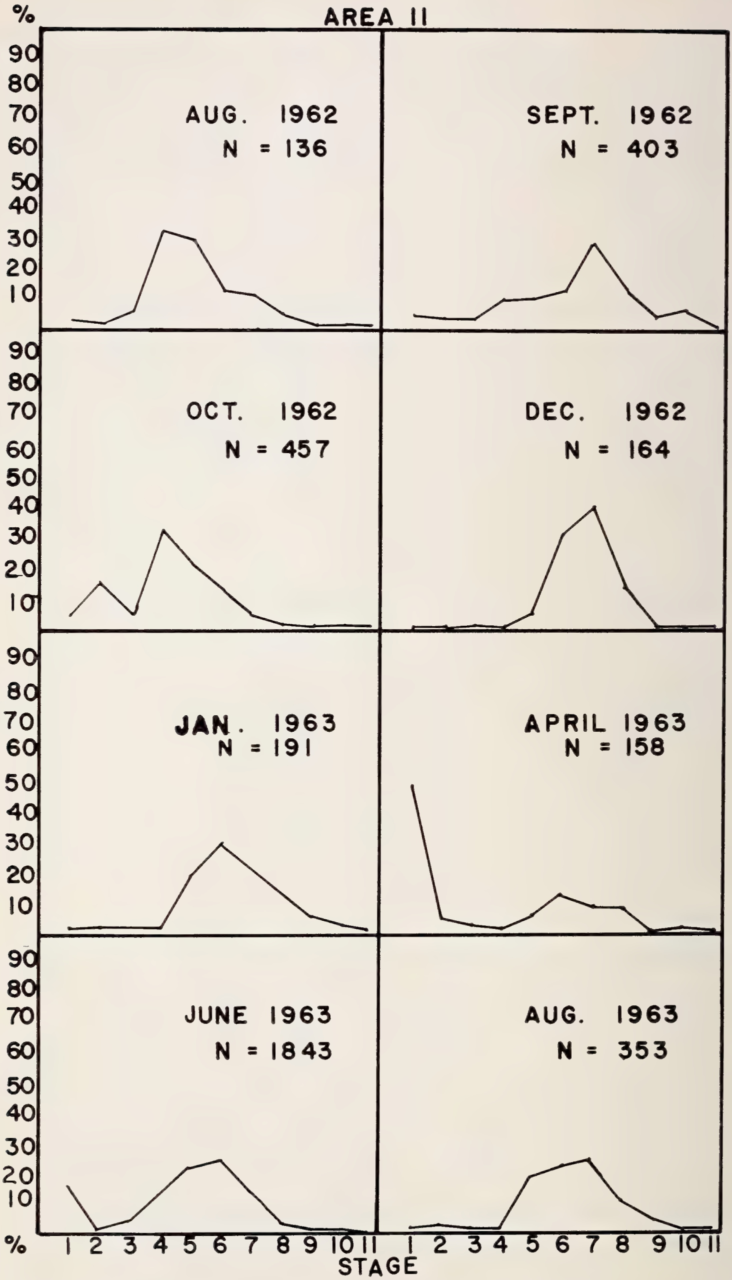

Fig. 3. Monthly occurrence of larval stages in Area II.

should be of value in locating offshore populations. It is possible that older stages could pass from the Caribbean to Florida without ecdyses; however, it may be deduced from the drift-bottle study that some of the objects carried by the surface currents of this area may spend some time in the eddies and slow moving currents that retard their northward movement.

It is possible that larval development is accelerated in the warm tropical waters of the Caribbean and lower Gulf of Mexico. If so the distance from the source of recruited larvae to Florida would be shorter than the distance in higher latitudes.

VERTICAL DISTRIBUTION AND DIURNAL MIGRATIONS

A phyllosoma larva is not a static object like a drift-bottle. Although planktonic in nature and at the mercy of prevailing currents, the larvae may inadvertently retard their northward movement by undergoing changes in vertical distribution. Harada (1957), George and Cawthorn (1963) and Johnson (1960a) suggested that the phyllosoma larvae follow the typical daily vertical migration of zooplankton (Moore, 1958). Our observations both in the laboratory and at sea agree with these data. In tanks at the Pigeon Key Field Station, early stage phyllosoma swam the length of a 12 foot tank to congregate in the dim light surrounding a flashlight beam. If the beam was moved to the other end of the tank all the larvae followed within 5-10 minutes.

Table 1 lists the data collected during cruise number 7, made in June 1963. During this cruise two one-meter nets were fished simultaneously at each station in an attempt to show a variation in the catch of each net during night and day. One net was fished just below the surface and well behind the boat, to reduce the chance of catching sargassum weed, which was abundant in the area. Every attempt was made to keep the top of the net not deeper than one foot. The second net was fished in the oblique manner, 300 feet to surface in 30 minutes. Both nets were fished for the same length of time. The deep net was brought out of the water as soon as it reached the surface to prevent it from taking surface plankton, as closing devices were not available. The data clearly show that the largest number of phyllosoma were collected by the deep net during day sampling, 7 AM to 7 PM, and by the surface net during the night. Almost no larvae were taken on the

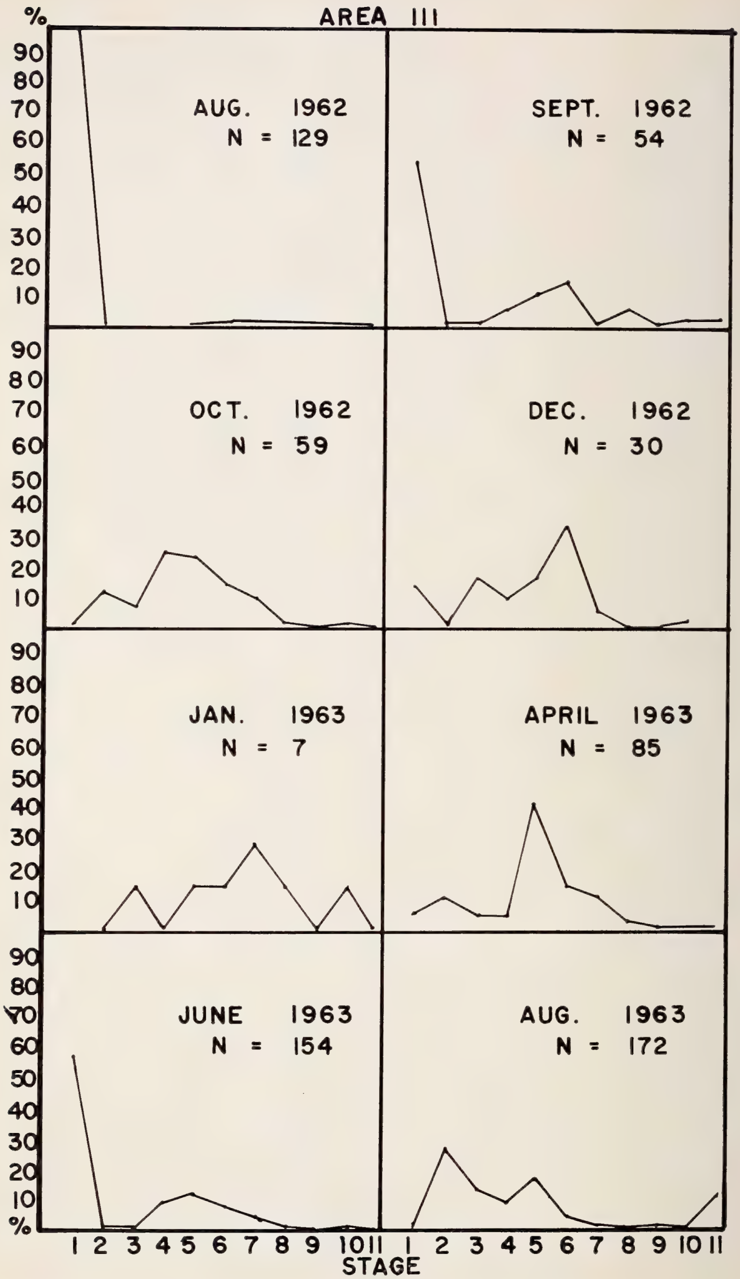

Fig. 4. Monthly occurrence of larval stages in Area III.

surface during day samples, and the few larvae that were collected by the deep net at night may have been inadvertently captured in surface water as the net was lowered and raised.

Differences in direction between surface and subsurface waters are not uncommon and are frequently described in oceanographic reports. These differences in current direction coupled with the vertical distribution and migration of phyllosoma larvae could aid in the retention of phyllosoma in a given area and would augment chances for some local recruitment in Florida. This must remain a speculation, however, until supporting evidence is developed.

SEASON OF HATCHING AND OCEANOGRAPHIC DISTRIBUTION

The first phyllosoma stage was collected every cruise except the one made in January when the youngest stage was stage II. The last stage (XI) was taken every trip except April. First stage post-larvae were collected only in April, June, and August. In no cruise did the range fail to extend from Stages II to X.

Such data suggest that hatching takes place throughout the year at various points in and below the area of study. Supporting evidence is given by Smith (1948b) and Holthuis and Zaneveld (1958), who found gravid female spiny lobsters in the Caribbean from October to June, and by Lewis (1951), who reported them in Florida from March to November.

In an attempt to show a progression in the modal sizes of phyllosoma transmigrating from the Caribbean to Florida and from Florida north, four sampling areas were set up; Area I, from latitude 20-22° N, including the Yucatan Straits and the waters north of the Yucatan Peninsula; Area II, between latitude 22-24° N, including the waters west of Cayo Arenas and east to Alligator Reef in the Florida Keys; Area III, the waters between latitude 24-26° N; and Area IV, a straight line due east of St. Augustine, Florida extending to the middle of the Gulf Stream. Area IV was sampled only during the months of July and August, 1962. Tables 2-4 give the data collected in each of the areas. Table 5 combines Areas I-III. Table 6 provides information obtained in the Gulf Stream east of St. Augustine. Monthly size frequency graphs are provided for each area (Figs. 2-5).

These tables and figures show no modal progression in size or stage between areas or from month to month. Geographically the

TABLE 5

Monthly data for Areas I-III incorporated

Date	Number Collected	Size Range	Mean Stage	Mean Deviation	Modal Stage	Modal Size	Number Samples	Per cent with Larvae	Avg. Temp.	Avg. Sal.	Moon Phase
Aug. 1962	1064	1.5-23.0	5	11.7	5	5.0	28	93	30.1	37.7	F.Q.
Sept. 1932	457	1.5-26.0	7	20.7	7	5.2	42	57	29.3	37.9	L.Q.
Oct. 1962	525	1.5-23.2	4	11.2	4	4.0	39	79	28.8	37.7	F.Q.
Dec. 1962	205	1.5-25.1	7	12.9	7	8.2	56	46	24.9	38.5	F.M.
Jan. 1963	198	2.3-25.2	6	12.7	6	7.2	26	57	24.9	38.5	F.M.
Apr. 1963	1244	1.4-21.0	1	6.05	1	1.7	77	51	25.5	37.3	N.M.
June 1963	2713	1.5-23.5	6	18.3	6	1.7	115	70	28.2	37.5	L.Q.
Aug. 1963	525	1.5-26.2	5	19.4	5	5.0	29	90	29.0	—	F.M.

larvae are spread almost uniformly throughout the areas sampled except for the area in the Yucatan Straits, where the narrow channel and less surface area probably account for a concentration of the larvae and more are taken per sample.

A small number of early stage phyllosoma larvae belonging to the genus *Panulirus* have been collected in the Gulf of Mexico west of St. Petersburg, Florida.

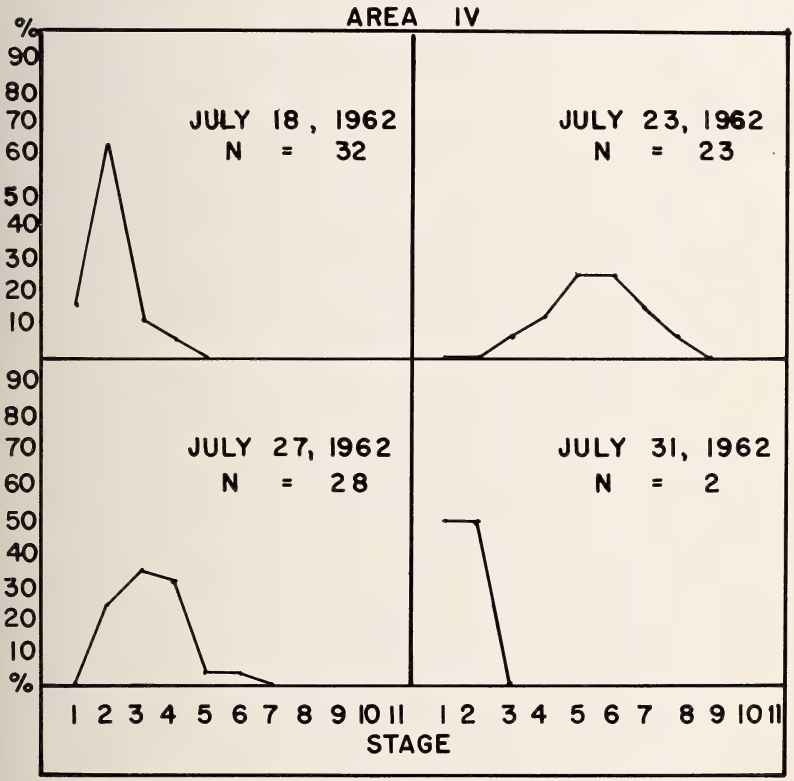

Fig. 5. Monthly occurrence of larval stages in Area IV.

Hydrography and Distribution of Larvae

Studies made at the Pigeon Key Field Station indicate that hatching takes place on offshore reefs on the ocean side of highway U. S. 1. Samples of the plankton taken over these reefs during the spawning period yielded numerous first stage phyllosoma larvae.

TABLE 6

Monthly data for Area IV, due east of St. Augustine, Florida

Date	Number Collected	Range Size	Mean Stage	Mean Deviation	Modal Stage	Modal Size	Number Station	Per cent with Larvae
July 18, 1962	32	1.5-8.0	2	4.1	2	2.3	12	33
July 23, 1962	23	3.0-13.8	5,6	6.5	5,6	—	12	50
July 27, 1962	28	2.0-6.0	3	7.5	3	3.0	6	16
July 31, 1962	2	1.8-2.2	—	0	—	—	8	13
Aug. 23, 1962	1	2.5	2	0	2	2.5	9	11
July, 1962	85	1.5-13.8	2	15.4	2	—	38	31

In samples taken farther offshore the percentage of stage I lessened and a wide size range was collected. From the bridges along U. S. 1 in the Florida Keys, 1237 samples produced only 7 phyllosoma larvae, viz.: three stage I collected in May 1963, and single specimens of stages I, III, VI, and VIII collected in August 1963. Prasad and Tampi (1957) and Johnson (1960b) reported similar findings and feel that there is a rapid offshore movement of the first stage. If this is the case in the Florida Keys, then this stage must enter the Gulf Stream to be carried toward northern waters. Some of these larvae may be able to re-enter coastal populations by being caught in one of the numerous eddies that lie along the eastern coast of the United States and in the Bahamas. Great numbers must drift northward with the Gulf Stream to oblivion in the North Atlantic.

Twenty-six per cent of the phyllosomas collected during the 8 cruises were in the first stage. The largest single catch of this stage was made in April, 1963, when 712 were collected in a 30 minute sample taken just northeast of Cabo Catoche, Yucatan. All the other samples containing large numbers of stage I were collected within 50 miles of land, but it was not uncommon to collect this stage more than 100 miles offshore.

The middle stages, IV through VII, accounted for the greatest number of phyllosomas collected. These were collected every month and in every area sampled indicating a good mixing of larval populations and a constant recruitment.

The last stage accounted for only one-half of one per cent of the total number collected. Small numbers were collected both inshore and offshore and on the surface as well as in the deep water.

Post-larvae were collected in the offshore waters of the Florida and Yucatan Straits during the months of April, June, and August and were collected in the inshore waters of the Florida Keys from April to August. Large numbers of post-larvae were reported in Miami from January to March (Lewis et al., 1952), and they occur throughout the year in the Indian River at Stuart, Florida (Witham et al., 1965). The post-larvae apparently may enter the inshore waters to undergo juvenile development, but their occurrence both inshore and offshore suggests metamorphosis takes place regardless of the suitability of location for survival.

TABLE 7

Drift-bottle return data

Bottle Number	Number Station	Date of Release	Release Locations Lat. N.	Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
77A	48	9/6/62	22.00	86.00	9/23/62	18	North of Snake Creek Bridge, Florida Keys
79A	48	9/6/62	22.00	86.00	1/4/63	119	Ocean Reef, Key Largo, Florida
2A	49	10/9/62	22.05	86.06	5/4/63	210	East of Matagorda, Texas
8	5	4/23/63	24.37	82.40	5/9/63	16	Boca Raton, Florida
11	5	4/23/63	24.37	82.40	5/20/63	25	Plantation Key, Florida Keys
13	6	4/23/63	24.38	83.00	5/23/63	14	Lantana, Florida
14	6	4/23/63	23.38	83.00	5/11/63	18	Delray Beach, Florida
16	6	4/23/63	24.38	83.00	5/13/63	20	Ft. Pierce Inlet, Florida
17	6	4/23/63	24.38	83.00	10/9/63	169	Dry Tortugas, Florida
20	7	4/24/63	24.29	83.13	6/12/63	49	Boca Chica Key, Florida Keys, Florida
21	7	4/24/63	24.29	83.13	5/14/63	20	Jade Beach, Ft. Lauderdale, Florida
23	7	4/24/63	24.29	83.12	5/19/64	360	Windley Key, Florida Keys, Florida
25	8	4/24/63	24.21	83.32	5/4/63	10	Malibu Lodge, Islamorda, Florida
29	8	4/24/63	24.21	83.32	7/15/63	82	East Side Plantation Key, Florida
30	8	4/24/63	24.21	83.32	6/27/63	64	Coral Gables, Florida
32	9	4/23/63	24.13	83.58	7/30/63	98	Coral Gables, Florida
34	9	4/24/63	24.13	83.58	5/18/63	24	Old Rhodes Key (N. end), Miami, Florida
35	9	4/24/63	24.13	83.58	9/2/63	111	Angelfish Key, E. of N. end, Key Largo, Florida
36	9	4/24/63	24.13	83.58	3/6/64	317	Angelfish Key, E. of N. end, Key Largo, Florida
42	10	4/24/63	24.09	84.16	6/30/63	67	Miami Beach, Florida
47	11	4/24/63	24.02	84.34	8/11/63	109	E. side Elliot Key, S. of Sands Cut, Miami, Fla.

TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
62	15	4/25/63	23.37	85.28	6/29/63	65	North Key Largo, Oceanside, Florida.
69	16	4/25/63	23.35	85.35	7/16/63	83	Palm Beach, Florida
72	16	4/25/63	23.35	85.35	7/13/63	81	Phipps Park, Lake Worth, Florida
79	18	4/25/63	23.21	86.17	6/26/63	62	Miami Beach, Florida
80	18	4/25/63	23.21	86.17	7/14/63	80	Ft. Lauderdale, Florida
83	18	4/25/63	23.21	86.17	6/12/63	48	Pompano Beach, Florida
85	19	4/25/63	23.18	86.36	6/1/63	37	Sebastian Inlet, Florida, near Grant, Florida
86	19	4/25/63	23.18	86.36	5/30/63	35	Vero Beach, Florida
89	19	4/25/63	23.18	86.36	5/22/63	27	Haufoune Park, Miami Beach, Florida
91	20	4/25/63	23.07	86.55	8/10/63	107	Grand Isle, La.
96	20	4/25/63	23.07	86.55	2/28/64	309	Arrecife dela Gallega, Bay of Vera Cruz, Mex.
98	21	4/25/63	22.59	87.13	10/9/63	167	3 miles N. Pepper Pk., Ft. Pierce, Florida
114	25	4/26/63	22.34	88.25	8/8/63	104	Travernier, Florida
119	24	4/26/63	22.41	88.16	9/29/63	156	St. Augustine Beach, Florida
120	24	4/26/63	22.41	88.16	7/27/63	92	Ft. Taylor Officer Club, Key West, Florida
126	23	4/25/63	22.42	88.16	9/4/63	111	Biscayne Bay, Miami, Florida
127	26	4/25/63	22.31	88.45	11/19/63	219	Radar Cameras, Melbourne Beach, Florida
131	26	4/25/63	22.31	88.45	9/23/63	150	Daytona Beach, Florida
135	27	4/26/63	22.29	89.00	6/10/63	45	Galveston, Texas
138	27	4/26/63	22.29	89.00	6/16/63	51	Cameron, La.
139	28	4/26/63	22.21	89.19	6/9/63	44	Bolivar Peninsula, Texas

TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
140	28	4/26/63	22.21	89.19	6/14/63	49	Gilchrist, Texas
149	29	4/26/63	22.58	88.01	6/6/63	41	Surfside Beach, Freeport, Texas
159	31	4/28/63	22.04	87.21	7/4/63	68	Matagorda, Texas
161	31	4/28/36	22.04	87.21	7/1/53	64	Sargent Beach, Texas
162	31	4/28/63	22.04	87.21	7/10/63	73	Green's Bayou, Matagorda Peninsula, Texas
164	32	4/29/63	21.35	86.08	8/23/64	116	Caillou Island, Louisiana
181	32	4/29/63	21.35	86.08	12/27/63	242	Man-o-War Cay, Bahamas
202	32	4/29/63	21.35	86.08	9/20/63	144	Bolivar Peninsula, Galveston, Texas
208	32	4/29/63	21.35	86.08	9/1/63	105	Whiskey Pass, La.
209	32	4/29/63	21.35	86.08	9/25/63	149	Ocean side of Key Largo, Florida
277	44	6/20/63	20.45	85.22	9/19/63	91	Vilano Beach, St. Augustine, Florida
278	44	6/20/63	20.45	85.22	8/8/63	50	Miami Beach, Florida
280	44	6/20/63	20.45	85.22	10/23/63	125	Padre Island, off Corpus Christi, Texas
284	44	6/20/63	20.45	85.22	9/16/63	88	Boca Raton, Florida
286	44	6/20/63	20.45	85.22	4/3/64	289	Tamaulipas, Mexico
289	44	6/20/63	20.45	85.22	6/20/63	106	Vero Beach, Florida
294	44	6/20/63	20.45	85.22	8/7/63	48	Crandon Park, Miami, Florida
296	44	6/20/63	20.45	85.22	10/15/63	117	Padre Island, Corpus Christi, Texas
297	44	6/20/63	20.45	85.22	9/9/63	93	Cape Canaveral Beach, Florida
300	38	6/19/63	20.33	87.00	9/2/63	75	Crystal Beach, Texas, Bolivar Peninsula

Summary

A large number of plankton samples were taken with 1 meter and ½ meter plankton nets in the waters of the Yucatan and Florida Straits. The absence of a progression of model size or stage for phyllosoma larvae of *Panulirus argus* from southern to northern stations or from month to month indicates that year around spawning takes place in the Caribbean. This assumption is supported by the continuous presence of gravid females. The wide size range throughout the period sampled is also consistent with widespread recruitment from the Caribbean.

Drift-bottle data indicate that the rate of flow of the surface water from the Yucatan Straits to Florida may be as fast as 30 miles a day, but many floating objects take longer because of eddies and slower currents. Moreover, in a laminated current system in which contiguous layers move in opposing directions, horizontal movements of vertically migrating plankton may be retarded. Phyllosoma larvae undergo such vertical migration.

Successful migration of planktonic animals over long distances is largely dependent upon length of larval life and speed of currents. Prevailing hydrographic conditions in the Yucatan and Florida Straits give strong evidence of the seeding of Florida waters with Caribbean hatched phyllosoma larvae. Information is now needed to show how these larvae enter coastal populations and what methods may be employed to retain greater numbers of them to insure their survival and growth. The international scope of current and future investigations emphasizes the need for cooperative efforts throughout the Caribbean area. Even though spawning in Florida is probably greatest in spring and summer, the year around delivery of larvae from the Caribbean and continuous recruitment of newly formed post-larvae makes year classes difficult to distinguish.

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TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
354	45	6/25/63	20.47	85.13	10/25/63	129	New Smyrna Beach, Florida
352	45	6/20/63	20.47	85.13	4/25/64	311	Brownsville, Texas
356	45	6/20/63	20.47	85.13	10/16/63	118	Jupiter Island, Florida
360	45	6/20/63	20.47	85.13	11/12/63	145	Matagorda Island, Port O'Connor, Texas
362	45	6/20/63	20.47	85.13	10/18/63	120	False Cape, Titusville Beach, Florida
366	45	6/20/63	20.47	85.13	10/27/63	129	Padre Island, Corpus Christi, Texas
373	45	6/20/63	20.47	85.13	10/4/63	106	Key Biscayne, Florida
374	45	6/20/63	20.47	85.13	10/4/63	106	Ft. Pierce, Florida
375	39	6/19/63	20.32	86.55	9/2/63	65	Delray Beach, Florida
377	39	6/19/63	20.32	86.55	2/14/64	252	Vera Cruz, Mexico
380	36	6/19/63	20.30	86.56	10/24/63	128	Grand Terre Island, Louisiana
386	36	6/19/63	20.30	86.56	10/18/63	121	Travernier, Florida Keys, Florida
391	36	6/19/63	20.30	86.56	11/19/63	153	Port O'Connor Gulf Beaches, Texas
395	39	6/19/63	20.32	86.55	3/17/64	272	Pelican Island, Galveston, Texas
397	36	6/19/63	20.30	86.56	9/28/63	101	Ponte Verda Beach, Neptune Beach, Florida
399	43	6/20/63	20.40	85.35	9/15/63	87	Crescent Beach, St. Augustine, Florida
401	43	6/20/63	20.40	85.35	10/5/63	107	Anastasia Island near St. Augustine, Florida
406	43	6/20/63	20.40	85.35	9/19/63	91	Daytona Beach, Florida
407	43	6/20/63	20.40	85.35	2/13/64	267	South of Miami, Florida
410	43	6/20/63	20.40	85.35	8/27/63	68	Vero Beach, Florida

TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Location Lat. N.	Release Location Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
426	46	6/21/63	21.01	85.13	10/7/63	108	Jensen Beach, Florida
427	46	6/21/63	21.01	85.13	9/28/63	99	Jupiter, Florida
428	46	6/21/63	21.01	85.13	9/26/63	92	Delray Beach, Florida
433	46	6/21/63	21.01	85.13	9/27/63	93	St. Augustine, Florida
436	47	6/21/63	21.46	85.06	10/11/63	102	Daytona Beach, Florida
440	47	6/21/63	21.46	85.06	11/20/63	121	St. Augustine, Florida
445	47	6/21/63	21.46	85.06	9/26/63	97	Titusville Beach, Florida
459	3	6/23/63	26.30	83.20	7/11/63	18	Smathers Beach, Key West, Florida
467	3	6/23/63	26.30	83.20	9/8/63	77	Key West, Florida
468	3	6/23/63	26.30	83.20	7/14/63	20	Cocoa Plum Beach, Marathon Shores, Florida
469	3	6/23/63	26.30	83.20	4/19/64	302	Padre Island, Texas
474	50	6/17/63	22.15	86.14	9/1/63	76	Miami, Florida
476	6	6/14/63	24.38	83.00	6/16/63	2	Garden Key, Tortugas, Florida
480	50	6/17/63	22.15	86.14	10/8/63	113	Daytona Beach, Florida
482	6	6/14/63	24.38	83.00	6/16/63	2	Garden Key, Tortugas, Florida
486	50	6/17/63	22.15	86.14	10/16/63	121	South New Smyrna Beach, Florida
487	6	6/14/63	24.38	83.00	6/14/63	0	Garden Key, Tortugas, Florida
488	50	6/17/63	22.15	86.14	9/9/63	84	Hollywood Beach, Florida
490	50	6/17/63	22.15	86.14	11/20/63	156	Julia Island, ocean side of Key Largo, Florida
492	42	6/20/63	20.42	85.57	11/28/63	161	Saddle Bunch Keys, off Key West, Florida

TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Release Locations Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
495	42	6/20/63	20.42	85.57	10/18/63	120	Ormond Beach, Florida
496	42	6/20/63	20.42	85.57	10/6/63	108	Plantation Key, Florida Keys, Florida
498	42	6/20/63	20.42	85.57	3/8/64	262	Julia Island, Florida Keys, Florida
503	42	6/20/63	20.42	85.35	9/26/63	98	N. of Ormond Beach, Florida
505	42	6/20/63	20.42	85.57	11/23/63	156	Marathon Shores, Florida
506	42	6/20/63	20.42	85.57	10/21/63	123	Cape Canaveral Beach, Florida
507	42	6/20/63	20.42	85.57	12/25/63	188	Boca Ciega Beach, Havana, Cuba
509	42	6/20/63	20.42	85.57	11/23/63	156	Padre Island, Corpus Christi, Texas
510	42	6/20/63	20.42	85.57	9/27/63	99	New Smyrna Beach, Florida
511	42	6/20/63	20.42	85.57	8/31/63	72	Jensen Beach, Florida
512	42	6/20/63	20.42	85.57	10/4/63	106	Duck Key, Florida Keys, Florida
518	6	6/14/63	24.39	83.00	6/15/63	1	Garden Key, Tortugas, Florida
519	40	6/20/63	20.41	86.25	9/21/63	93	Lower Matecumbe Key, Florida
523	40	6/20/63	20.41	86.25	10/17/63	119	Ormond Beach, Florida
525	40	6/20/63	20.41	86.25	9/29/63	101	Marathon Shores, Florida
569	35	6/19/63	20.34	86.55	4/28/64	324	Port O'Connor, Texas
570	35	6/19/63	20.34	86.55	10/15/63	188	Sands Key, Miami, Florida
571	35	6/19/63	20.34	86.55	9/25/63	98	Tavernier, Florida
572	35	6/19/63	20.34	86.55	10/17/63	120	Daytona Beach, Florida
576	35	6/19/63	20.34	86.55	10/8/63	111	Ormond Beach, Florida

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TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
578	35	6/19/63	20.34	86.55	9/24/63	97	Stuart, Florida
580	35	6/19/63	20.34	86.55	10/13/63	116	Miami Beach, Florida
582	35	6/19/63	20.34	86.55	10/10/63	109	New Smyrna Beach, Florida
612	34	6/18/63	20.41	86.23	9/28/63	102	Padre Island, Corpus Christi, Texas
629	33	6/18/63	20.56	86.41	10/12/63	116	New Smyrna Beach, Florida
634	33	6/18/63	20.56	86.14	11/24/63	159	Padre Island, Corpus Christi, Texas
639	2	6/23/63	26.43	83.10	10/20/63	119	Duck Key, Florida
642	2	6/23/63	26.43	83.10	3/20/64	272	Spanish Cay, Bahamas
643	2	6/21/63	26.43	83.10	9/19/63	90	Ft. Pierce, Florida
644	2	6/23/63	26.43	83.10	7/17/63	24	Woman Key, Key West, Florida
649	2	6/23/63	26.43	83.10	8/3/63	41	Marathon, Florida
650	2	6/23/63	26.43	83.43	10/28/63	127	St. Lucie Inlet, Stuart, Florida
655	1	6/23/63	27.00	82.57	7/8/63	15	Green Key, New Port Richey, Florida
657	1	6/23/63	27.00	82.57	7/20/63	27	Flor-A-Mar Beach, New Port Richey, Florida
658	1	6/23/63	27.00	82.57	8/25/63	61	Manor Beach, New Port Richey, Florida
659	1	6/23/63	27.00	82.57	7/8/63	15	Flor-A-Mar Beach, New Port Richey, Florida
660	1	6/23/63	27.00	82.57	7/8/63	15	Flor-A-Mar Beach, New Port Richey, Florida
662	1	6/23/63	27.00	82.57	7/8/63	15	New Port Richey, Florida
663	47	6/21/63	21.46	85.06	9/27/63	98	New Smyrna Beach, Florida
665	47	6/21/63	21.46	85.06	10/3/63	104	St. Augustine, Florida
668	47	6/23/63	21.46	85.06	10/17/63	116	Daytona Beach, Florida

TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Release Locations Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
669	47	6/21/63	21.46	85.06	10/5/63	106	St. Augustine, Florida
670	47	6/21/63	21.46	85.06	10/2/63	103	Hollywood Beach, Florida
671	47	6/21/63	21.46	85.06	10/18/63	119	Daytona Beach, Florida
678	47	6/21/63	21.46	85.06	2/9/64	233	Padre Island, Texas
680	47	6/21/63	21.46	85.06	10/17/63	118	Padre Island, Texas
683	47	6/19/63	21.46	85.06	9/25/63	96	Cape Canaveral, Florida
684	47	6/21/63	21.46	85.06	9/25/63	96	Cocoa Beach, Florida
685	47	6/21/63	21.46	85.06	9/24/63	95	Melbourne Beach, Florida
769	A2	8/9/63	22.22	85.40	9/24/63	46	New Smyrna Beach, Florida
774	A2	8/9/63	22.22	85.40	9/17/63	39	Port Everglades Jettys, Florida
784	A2	8/9/64	22.22	85.40	4/5/64	240	Matagorda Island, Port O'Conner, Texas
858	A4	8/10/63	23.31	87.10	8/30/63	20	Delray Beach, Florida
860	A4	8/10/63	23.31	87.10	11/20/63	101	Cocoa Beach, Florida
867	A4	8/10/63	23.31	87.10	10/9/63	60	Flagler Beach, Florida
868	A4	8/10/63	23.31	87.10	4/4/64	238	South Padre Island, Texas
869	A4	8/10/63	23.34	83.28	9/25/63	46	New Smyrna Beach, Florida
870	A4	8/10/63	23.31	87.10	10/7/63	58	Jacksonville Beach, Florida
875	A4	8/10/63	23.31	87.10	9/26/63	47	Satellite Beach, Florida
877	A4	8/10/63	23.31	87.10	9/1/63	22	West Palm Beach, Florida
886	A4	8/10/63	23.31	87.10	10/8/63	59	Between Ormond and Flagler Beach, Florida
898	A4	8/10/63	23.31	87.10	9/27/63	48	St. Augustine, Florida

TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
7624	32	4/29/63	21.35	86.08	9/2/63	126	Golden Beach, Dade County, Florida
7625	32	4/29/63	21.35	86.08	12/28/63	244	Lantana, Florida
7641	32	4/29/63	21.35	86.08	7/20/63	82	Golden Beach, Miami, Florida
7651	32	4/29/63	21.35	86.08	11/27/63	212	Ormond Beach, Florida
7665	32	4/29/63	21.35	86.08	7/10/63	72	Palm Beach, Florida
7808	32	4/29/63	21.35	86.08	10/16/63	170	Hollywood Beach, Florida
7810	32	4/29/63	21.35	86.08	10/20/63	174	Titusville, Florida
7876	32	4/29/63	21.35	86.08	11/24/63	209	Barracuda Key, near Key West, Florida
7886	32	4/29/63	21.35	86.08	10/3/63	157	Ft. Pierce, Florida
7892	32	4/29/63	21.35	86.08	9/28/63	152	New Smyrna Beach, Florida
7898	32	4/29/63	21.35	86.08	9/28/63	152	Indialantic, Florida
7936	32	4/29/63	21.35	86.08	9/25/63	149	New Smyrna Beach, Florida
7955	32	4/29/63	21.35	86.08	2/15/64	302	Delray Beach, Florida
8096	32	4/29/63	21.35	86.08	9/22/63	146	Plantation Key, Florida Keys, Florida
7441	33	6/18/63	20.56	86.41	10/17/63	120	Hollywood, Florida
7616	33	6/18/63	20.56	86.41	10/10/63	111	New Smyrna Beach, Florida
8090	44	6/20/63	20.45	85.22	9/27/63	99	Port Canaveral, Florida
8098	33	6/18/63	20.56	86.41	9/16/63	90	Greyhound Key, Florida Keys, Florida
8401	44	6/19/63	20.45	85.22	10/20/63	123	Matagorda Beach, Texas
8422	35	6/19/63	20.34	86.55	11/10/63	144	Flamingo, Florida

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TABLE 7 (cont.)

Drift-bottle return data

Bottle Number	Station Number	Date of Release	Release Locations Lat. N.	Release Locations Long. W.	Date of Retrieval	Days Elapsed	Area of Retrieval
8447	37	6/19/63	20.36	87.08	11/4/63	138	Padre Island, Texas
8455	35	6/19/63	20.34	86.55	9/28/63	101	New Smyrna Beach, Florida
8480	45	6/20/63	20.47	85.13	10/7/63	109	Hillsboro Beach, Pompano Beach, Florida
8484	36	6/19/63	20.30	86.56	9/17/63	90	Ormond Beach, Florida
8489	38	6/19/63	20.33	87.00	1/12/64	207	Elliott Key, E. side, near Miami, Florida

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